(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) Publication number: **0 160 179**
A2

(12) EUROPEAN PATENT APPLICATION

(21) Application number: 85102476.0

(22) Date of filing: 05.03.85

(51) Int. Cl.⁴: B 05 B 5/02

(30) Priority: 30.04.84 DE 3416093

(43) Date of publication of application:
06.11.85 Bulletin 85/45

(84) Designated Contracting States:
AT CH DE FR GB IT LI SE

(71) Applicant: J. Wagner AG
Industriestrasse
CH-9450 Altstätten(CH)

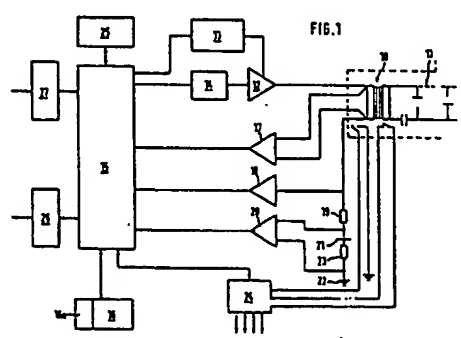
(72) Inventor: Zylka, Hans-Joachim
Pertana
CH-9478 Azmoos(CH)

(74) Representative: Patentanwälte Dipl.-Ing. Klaus Behn
Dipl.-Phys. Robert Münzhuber
Widenmayerstrasse 6/IV
D-8000 München 22(DE)

(54) Electronic high-voltage generator for electrostatic sprayer devices.

(57) A high-voltage generator for electrostatic sprayer device is disclosed whereby a frequency-clocked power amplifier is employed for the feed of a transformer connected preceding a high-voltage cascade, this power amplifier being connected to a controllable low-voltage d.c. voltage source and to a controllable frequency generator, whereby the control of the d.c. voltage source and of the frequency generator ensues by a microcomputer such that the transformer is optimally matched (or: balanced) for all voltages appearing at the high-voltage output of the cascade.

FIG.1



EP 0 160 179 A2

ELECTRONIC HIGH-VOLTAGE GENERATOR FOR ELECTROSTATIC SPRAYER DEVICES

The invention relates to an electronic high-voltage generator for electrostatic sprayer devices comprising a charging electrode, according to the preamble of patent claim 1.

Various embodiments of this type of high-voltage generator are commercially available, whereby they either represent a separate element connected to the spray gun via a high-voltage cable or, on the other hand, transformer and high-voltage cascade are accomodated in the gun and are connected via a low-voltage line to the unit containing the other components of the high-voltage generator. When producing such sprayer systems, the individual electronic components are designed such, particularly an oscillator having such an oscillation frequency for clocking the power amplifier, that the high-voltage generating ensues with the lowest possible power losses, in particular that the transformer functions optimally loss-free (resonant range). Despite this pre-matching, however, considerable power losses occur in the practical operation of such sprayer systems, particularly because the pre-matching is necessarily based on fixed values with respect to the connecting line between high-voltage generator or, respectively, high-voltage generating part and gun as well as with respect to the load. It is precisely the load, however,

that is dependent on the distance between charging electrode and the workpiece to be sprayed, the type of sprayed material and the like which is subject in practice to considerable changes or, respectively, fluctuations, particularly in the case of hand sprayguns. The consequence of these considerable losses is not only an inefficient operation but also the requirement to see to a corresponding heat dissipation, for instance at series resistors. In sprayguns wherein the transformer and high-voltage cascade are accomodated in the gun, the further disadvantage derives that, in order to avoid overheating damage, limits are placed on the miniaturization of these components, this leading to the fact -- particularly in the case of hand sprayguns -- that they are relatively large and heavy and, thus, unwieldy.

It is therefore the object of the present invention to perfect an electrostatic high-voltage generator of the said type intended for the operation of electrostatic sprayer devices such that an automatic matching (or: balancing) in the direction of minimum power losses continuously ensues during practical operation. The solution of this object derives from the features of the characterizing part of patent claim 1.

The invention is based on the perception that the powers losses occurring in practice given the known high-voltage generators are particularly based on the fact that the resonant range of the transformer shifts given load changes, i.e. this transformer no longer operates in the optimum power range. In order to then be able to undertake a frequency matching, the possibility must be created of being able to vary the frequency of the power amplifier driving the primary side of the transformer. A controllable frequency generator is therefore employed in accord with the invention for clocking the power amplifier, namely instead of the standard oscillators oscillating in a specific frequency. The control of this frequency and, over and above this, the control of the low-

voltage d.c. voltage source then ensues by means of a microcomputer which continuously and constantly undertakes the optimum power-wise matching on the basis of a control algorithm. The voltage at the low-voltage d.c. voltage source and, thus, the high-voltage at the putput of the high-voltage cascade is thereby set and controlled according to a precribed rated value (and) the frequency of the frequency generator is power-optimally selected or, respectively, controlled by the computer. As a result of this nearly loss-free high-voltage generating in all operating conditions, an energy saving derives on the one hand and, on the other hand, a significant reduction in the heat generated by the electronic components, particularly the transformer, (also) derives. Given, for example, the said sprayguns with integration of transformer and cascade, thus, it is possible to keep these component parts extremely small employing modern electronics and, thus, to execute the gun small and lightweight without any risk of overheating of the electronic components.

In a further development of the invention according to patent claim 2, the spray current, i.e. the current flowing between the charging electrode and the workpiece to be sprayed, is identified, whereby the microcomputer then keeps the voltage essentially constant up to a prescribed spray current threshold on the basis of the identified spray current values, but reduces the voltage when this threshold is reached or, respectively,exceeded. In other words, when the gun nears the workpiece, this being connected with an increase in the spray current, the voltage is first held at an essentially constant value, whereas the voltage is reduced after a specific distance (spray current threshold) and the danger of arcing is thus avoided. Thus, work can still be carried out hazard-free even within the threshold distance, whereby the optimum matching (minimum loss) continues to be guaranteed. Although so-called proximity-switches have already been disclosed, for

example in the European patent application 0 092 404, wherein the voltage is reduced as the gun approaches the workpiece, these known circuits are relatively involved, are hardly in the position of keeping the voltage constant before the threshold is reached and contributes nothing to a matching of the high-voltage generator precisely given the greatly fluctuating operating conditions in this case. Over and above this, the identification of the spray current in accord with patent claim 3 in the invention ensues in a very simple, unproblematical and yet precise measuring method.

According to the other sub-claims, the inventive high-voltage generator can be expanded by selection units, control elements and interface units, whereby numerous possibilities derive with respect to inputting and displaying data, prescribing specific sequences and linking with other sprayer devices and/or other data processing devices.

Shown in the drawing are:

Fig. 1 a block diagram of an embodiment of the inventive high-voltage generator;

Fig. 2A and 2B diagrams for explaining the control dependent on spray current; and

Fig. 3A, 3B and 3C sketches for explaining a display means.

In the block diagram shown in the drawing, 10 references a high-voltage transformer whose secondary side is connected to the input of a high-voltage cascade 11. The high-voltage output of the cascade 11 leads to a high-voltage electrode (not shown). Transformer 10, high-voltage cascade 11 and high-voltage electrode are standard components of known electrostatic sprayguns with high-voltage generating integrated in the gun.

The primary side of the high-voltage transformer 10 is supplied via a feed cable (not shown) from a power amplifier 12 which, just like the components explained below, is situated at a location removed from the spray gun, preferably in the housing of a combined feed and control unit. The power amplifier 12 is supplied with d.c. voltage from a controllable voltage source 13, for instance a clocked power pack. Further, the required clock frequency is impressed on the power amplifier 12 by a frequency generator 14, whereby the generator 14 is a matter of a dc-controlled, regulable frequency generator - this being of essential significance. Voltage source 13 and frequency generator 14 are connected via control lines to a microcomputer 15 which undertakes the control (or: regulation) of these two component parts. The microcomputer 15 is selectable by a drive element 16 which comprises a manually actuatable keyboard as well as a display means for displaying interesting data. Further, the microcomputer 15 is continuously supplied with data about the events occuring in the high-voltage generator, whereby the respective actual voltage values are identified by a circuit (or: logic) unit 17 and the respective actual current values of the primary side of the transformer 10 are identifidd by a circuit (or: logic) unit 18 and are forwarded to the microprocessor 15 as informational data upon appropriate data editing. The circuit of the two units 17 and 18 thereby derives from the drawing whereby 19 references a low-value resistor. Over and above this, the microprocessor 15 is supplied with informational data about the size of the respective spray current, i.e. the current between the high-voltage electrode and the grounded workpiece, being supplied therewith, namely, by the circuit unit 20. The circuit unit 20 thereby determine the spray current in such fashion that the current flux between the electronics ground indicated at 21 and a grounding 22 is measured, namely upon interposition of a high-value resistor 23. In this fashion, the spray current which is difficult to access in direct

measurements can be easily and nonetheless exactly identified.

24 references an input-output control element which is in communication with the microcomputer 10 and actuation elements of the spraygun, for instance the trigger members for high-voltage, spray material feed and compressed air feed, and which controlls certains sequences, for instance opening the spray material valve only after the high-voltage has been switched on, and indicates errors under given conditions. A standard monitoring logic unit 25 assumes the monitoring of the program control of the microcomputer 15. 26 and 27, finally, reference interface circuit (or: logic) units, whereby the unit 26 is a matter of an interprocessor interface for producing combinations for the purpose of data or, respectively, instruction exchange (for example, controlling a plurality of sprayguns from a central (location)) and the unit 27 is a matter of a serial interface which enables a connection to high-ranking computer systems.

The high-voltage generator works in the following fashion. The operator inputs the value for the high voltage desired at the charging electrode via the keyboard of the drive element 16. During the entire spraying operation, the microprocessor then controls the voltage of the voltage source 13 and the frequency of the frequency generator 14 such that, on the one hand, the desired voltage remains constant and, on the other hand, the primary current of the fransformer 10 remains at the most favorable value (minimum) in terms of performance. An optimum spray effect (constant high-voltage) and a minimum power loss (optimum matching) are thus guaranteed regardless of the respective loads and load fluctuations. In addition to the input of the desired high-voltage at the charging electrode, however, a spray value threshold is also input into the

microcomputer by means of the keyboard. When this threshold is reached or exceeded, this being communicated to the computer 15 by the circuit (or: logic) unit 20, then the computer 15 reduces the voltage of the voltage source 13 and, thus, the high-voltage at the charging electrode, namely such that the spray current then remains essentially constant. Fig. 2A shows the characteristic of the spray current I_S and Fig. 3A shows the characteristic of the high-voltage U at the charging electrode, namely respectively entered over the distance of the charging electrode from the workpiece. The broken vertical line thereby indicates the threshold of the spray current or, respectively, of the critical distance. This regulation deriving from the two diagrams enables hazardfree work up to minimum distances between charging electrode and workpiece, whereby the control can be undertaken such that the voltage completely collapses immediately before the charging electrode contacts the workpiece (contact protection). The power-wise matching thereby also continues to be carried out during this "close operation", i.e. no significant power losses and, thus, no heating of the electronics modules occur during this operating condition either.

Various setting and operating data can be displayed to the operator on the display unit of the drive element 16. In particular, a display of the selected voltage, of the selected spray current threshold and of the size of the spray current will be undertaken. A particularly elegant display for these three values is composed of a switchable luminescent diode band such as shown in Figs. 3A, 3B and 3C. The luminescent band referenced 30 in Fig. 3A thereby represents the display for the high-voltage that has been set, whereby the voltage value derives from the length of the band 30. This display will thus remain constant

during operation unless the spray current threshold is exceeded. The condition shown in Fig. 3B in which the set spray current threshold is displayed, namely by the non-illuminated diode dividing the luminescent band 30 into two sub-bands 31, 32, can be achieved by means of switching over. By further switching, finally, the condition of Fig. 3C is reached, wherein the actual spray current is displayed. Only a single luminescent diode 33 is then illuminated for this display of the spray current. The advantage of this display consists therein that only one luminescent diode array is required for displaying three values, namely voltage U, threshold SW and spray current I_S.

On the basis of the data existing in the microcomputer, information can be derived which are essential for error diagnosis, for example allow identification in case of an error as to whether it is a matter of a defect of the cascade, a line interruption, etc. Further, both the pre cription as well as the recognition or, respectively, display of specific sequences and events can be achieved by means of the input-output control unit 24, for example the prescription of interlocks (for instance, paint valve is not opened until after high-voltage has been switched on) or the display of errors. Combinations of a plurality of logics can be executed by means of the inter-processor interface circuit 26 for the purpose of data or, respectively, instruction exchange, for instance when a plurality of spray guns are to be controlled proceeding from a central (location) or when a workpiece grounding monitor is to be connected, whereby the high-voltage then automatically disconnects given deficient workpiece grounding. When the high-voltage generator is to be employed in combination with higher-ranking computers, this can ensue by means of the serial interface 27; nearly unlimited possibilties thereby derive for automatic spraying systems

with autonomous paint changing and the like.

The programming of the microcomputer is not the subject matter of the present invention, so that there is no need to explain an example of a program. It should merely be mentioned that programming comercially available microcomputers - whereby this is meant to include the combination of a microprocessor and data store - such or, respectively, providing it with such a program that the said algorithm control ensues presents no difficulties.

Merely by way of a numerical example, let it be indicated that the d.c. voltage source 13 supplies a d.c. voltage of 25 V given a d.c. current of 0,5 through 2A (and) the frequency generator 14 supplies a clock frequency of 26 kHz.

Of course, the invention is not limited to the exemplary embodiment that has been shown and explained, rather numerous modifications thereof are possible without departing from the scope of the invention. This relates particularly to the type and circuitry of the individual electronic components. What is essential, however, is that the microcomputer controls voltage and current such that an optimum matching is always given, this, referring to the primary side of the transformer, corresponding to maximum amplitude given minimum current.

Patent Claims

1. Electronic high-voltage generator for electrostatic sprayer devices comprising a charging electrode, said sprayer devices being formed of a controllable low-voltage d.c. voltage source, a frequency-clocked power amplifier which converts the d.c. voltage into an alternating voltage, of a transformer transforming the low-voltage alternating voltage into a medium high-voltage alternating voltage, and of a high-voltage cascade converting the medium high voltage alternating voltage into a high-voltage d.c. voltage, particularly for hand sprayguns wherein the transformer and the cascade are integrated in the gun, characterized in that the power amplifier (12) is clocked by a d.c.-voltage-controlled, regulable frequency generator (14); in that the low-voltage source (13) and the frequency generator (14) are controlled by a microcomputer (15) such that the transformer (10) is optimally matched performance-wise for all voltage appearing at the high-voltage output of the cascase (11), i.e. its primary current thus remains in the appertaining minimum; and in that the actual values of primary voltage and current of the transformer (10) are continuously supplied as informational data to the micro-computer (15) via circuit (or: logic) units (16, 17).

2. High-voltage generator according to claim 1, characterized by a circuit (or: logic) unit (18) identifying the spray current between charging electrode and grounded workpiece to be sprayed, this unit (18) continuously supplying the actual values of the spray current to the microcomputer (15) as informational data; and in that the microcomputer (15) controls the low-voltage d.c. voltage source (13) such that the high-voltage at the charging electrode remains essentially constant up to a prescribed spray current threshold (and) is reduced when this threshold is reached or, respectively, exceeded.

3. High-voltage generator according to claim 2, characterized in that the circuit unit (18) measures the current flux between electronics ground (21) and ground (22) for the identification of the spray current.

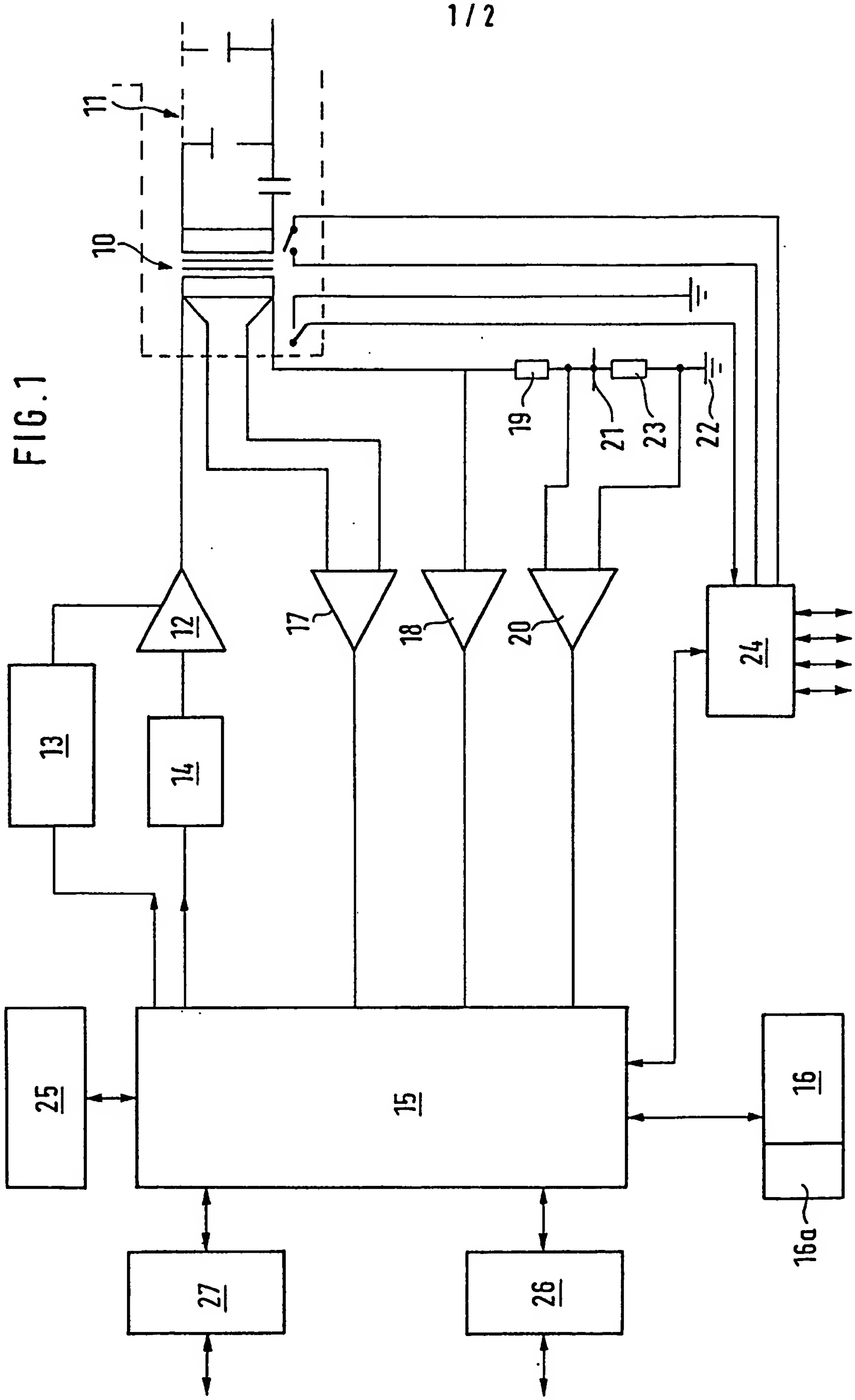
4. High-voltage generator according to one of the claims 1-3, characterized by a drive element (16) connected to the microcomputer (15) (and) comprising selection keyboard and display unit (16a).

5. High-voltage generator according to claim 4, characterized in that the display unit (16a) comprises a switchable luminescent diode band display.

6. High-voltage generator according to one of the claims 1-5, characterized by an input-output control element (24) which is connected to the microcomputer (15), to the high-voltage transformer (10) and actuation elements of the sprayer device and which controls spraying sequences.

7. High-voltage generator according to one of the claims 1-6, characterized by at least one interface circuit unit (26, 27) for producing interprocessor or serial linkages.

FIG.1



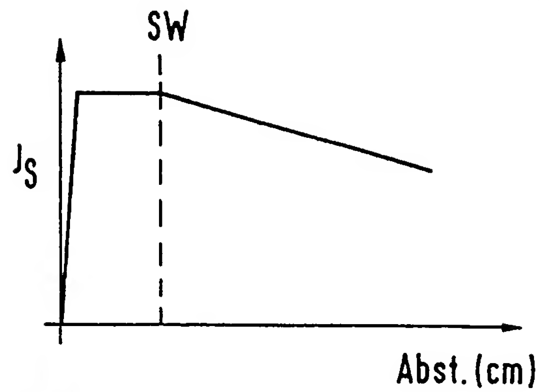


FIG. 2A

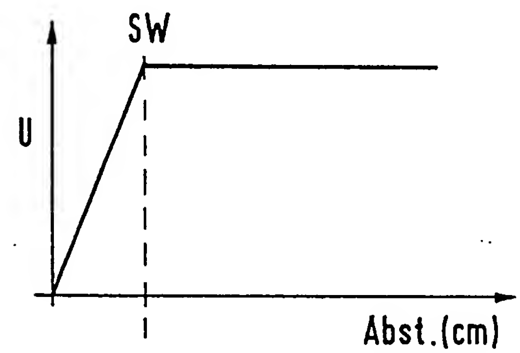


FIG. 2B

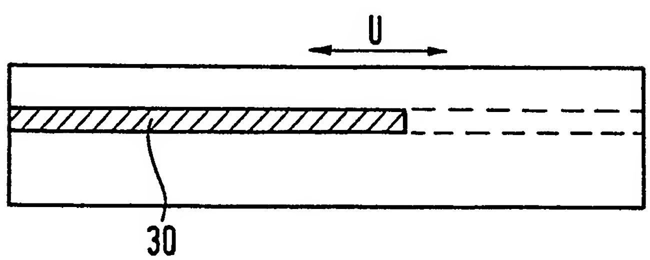


FIG. 3A

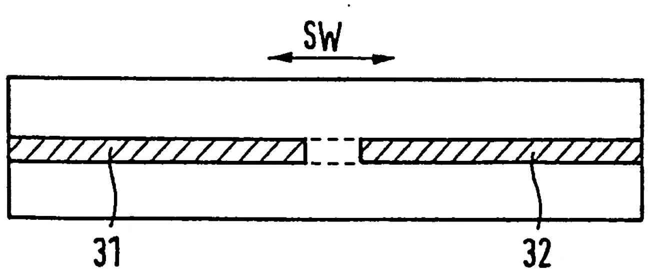


FIG. 3B

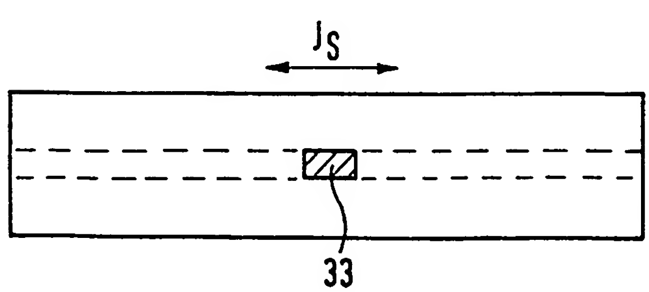


FIG. 3C